

# Photovoltaic Training Highlights



Program Funded By:

Sacramento Municipal  
Utility District  
&  
California Solar Energy  
Industries Association

Instructional Design By:

Rodney Slaughter



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## INTRODUCTION

### Technical Review

Jon Bertolino  
Sacramento Municipal Utilities District

Les Nelson CAL SEIA	Sue Kateley California Energy Commission
Lee Parker, Captain Modesto Fire Department	Scott Corrin, Fire Marshal U.C. Riverside Fire Department
Bob Gill, Chief Central Calaveras County Fire & Rescue	Russ Tingley, Fire Chief Hermosa Beach Fire Department
Howard Cooke, Fire Inspector Sacramento Fire Department	Dirk Drossel, Fire Inspector Burbank Fire Department

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## INTRODUCTION

**Program Goal:**

To provide fire service personnel with an awareness of photovoltaic systems, so that you can make informed decisions and operate safely during an emergency.

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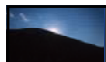

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	<h2 style="text-align: center;">INTRODUCTION</h2>
	<p><b>Course Materials:</b></p> <ul style="list-style-type: none"> <li>• Student Manual</li> <li>• Student Handout</li> <li>• Instructor Guide</li> <li>• Powerpoint Presentation</li> </ul> <p>Download the training program at:</p> <p><a href="http://osfm.fire.ca.gov/training/photovoltaics.php">http://osfm.fire.ca.gov/training/photovoltaics.php</a></p> <p><a href="http://calseia.org/emergency-response.html">http://calseia.org/emergency-response.html</a></p>

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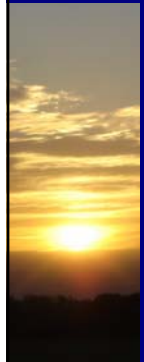
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	<ul style="list-style-type: none"> <li><input checked="" type="checkbox"/> INTRODUCTION</li> <li><input type="checkbox"/> CELLS AND COMPONENTS</li> <li><input type="checkbox"/> PV PERFORMANCE</li> <li><input type="checkbox"/> PV APPLICATIONS</li> <li><input type="checkbox"/> CODES AND STANDARDS</li> <li><input type="checkbox"/> EMERGENCY RESPONSE</li> </ul>

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<div data-bbox="168 1402 756 1480"></div> <p style="text-align: center;">What are the chances of responding to an emergency where a photovoltaic system has been installed?</p>
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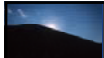
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## INTRODUCTION

By 2010, 2.5 gigawatts of PV production is projected worldwide

California is the National leader  
35,000 grid-connected systems

California's Goal:  
One million solar roofs by 2017

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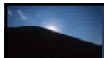
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## INTRODUCTION



Livermore, California – Multi-family housing development outfitted with PV electric systems- the wave of the future!

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Are photovoltaic systems safe to operate around?

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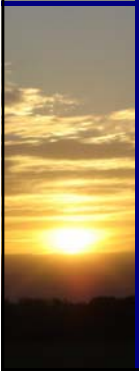
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	<h2 style="text-align: center;">PV CELLS &amp; COMPONENTS</h2>
	<p><b>SOLAR FACTS</b></p> <p>In the Northern Hemisphere, most photovoltaic systems are orientated towards true south to maximize the amount of light falling on the photovoltaic panels</p> <p>Peak sun per day is about 5 hours, between 10 am and 3 pm (peak energy production)</p> <p>The intensity can be diminished according to the micro climate and site specific conditions (shade &amp; temperature)</p>

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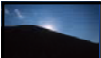
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	<h2 style="text-align: center;">PV CELLS &amp; COMPONENTS</h2>
	<p><b>Anatomy of a Solar Cell</b></p> <p>The PV cell is the smallest unit of the PV system</p> <p>There are two types of manufactured PV's:</p> <ul style="list-style-type: none"> <li>•Silicon cell (monocrystalline &amp; polycrystalline)</li> <li>or</li> <li>•Amorphous silicon</li> </ul> <p>PV cell has a thin layer of silicon 1/100th of an inch</p> <p>Silicon is layered with other materials to create the photoelectric reaction</p>

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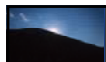
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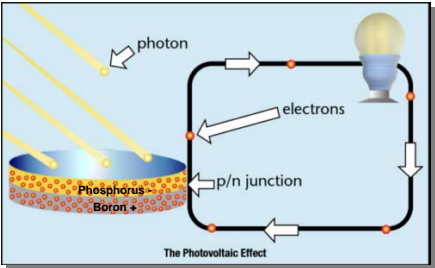
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## PV CELLS & COMPONENTS

### The Photovoltaic Effect



The diagram illustrates the photovoltaic effect. On the left, a cross-section of a p-n junction is shown, with a phosphorus layer (n-type) and a boron layer (p-type). Yellow arrows labeled 'photon' point towards the junction. On the right, a circuit diagram shows a light bulb connected to the p-n junction. Arrows labeled 'electrons' indicate the flow of current from the n-type layer, through the bulb, and back to the p-type layer. The entire process is labeled 'The Photovoltaic Effect' at the bottom.

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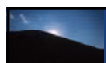
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## PV CELLS & COMPONENTS

### Monocrystalline &

Modules have output capacities of 14 to 15%

Monocrystalline achieves the highest efficiency in electric energy production

Its production cost is higher than other silicon types

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## PV CELLS & COMPONENTS

### Polycrystalline

Pure molten silicon is cast into molds, then sliced into wafers, doped and assembled



Polycrystalline is lower in conversion efficiency compared to Monocrystalline, averaging about 12 to 14% output capacity

Installation of polycrystalline modules on a rack system.

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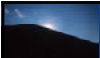
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## PV CELLS & COMPONENTS


### Amorphous



A semitransparent amorphous silicon product used as a gas station canopy in Fairfield, California

Top - looking down on the canopy

Bottom - looking up through the canopy



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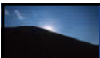
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## PV CELLS & COMPONENTS

### The Photovoltaic System Includes

Cells/Modules/Strings/Array  
(Tiles or Shingles)

Optional Batteries  
(Batteries required for off-grid systems)

Battery Controller

Inverter

Mounting Systems

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## PV CELLS & COMPONENTS


### Photovoltaic Modules

PV cells connected in series and parallel – the voltage and amperage is accumulated to achieve the desired electrical output

Photovoltaic cells connected together form a PV module

Weather-proof electrical connections connect modules together

In rare occasions junction boxes can overheat and can lead to roof damage and potential fire



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
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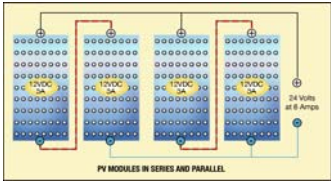


## PV CELLS & COMPONENTS

### Photovoltaic Array

The modules wired together in series to accumulate voltage, and the strings are wired together in parallel to increase amperage, collectively they form the array

#### Array in Series and Parallel



PV MODULES IN SERIES AND PARALLEL.

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## PV CELLS & COMPONENTS

### Photovoltaic Array

A PV system in the 3 to 4 kilowatt range would meet most homeowner's electricity needs

A 30 module array would operate at over 4,000 watts and weigh approximately 900 to 1,050 pounds

This weight spread equally over a 420 square foot area of the roof would result in a roof weight load of 2.5 pounds per square foot

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## PV CELLS & COMPONENTS

### Off-Grid Systems



Pinnacles National Monument in California installed a 9.6-kilowatt photovoltaic system. It eliminates the fuel bill for a diesel generator that produced 143 tons of carbon.

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## PV CELLS & COMPONENTS

### OFF-GRID (DC to AC Systems)



This PV system includes:

- Solar Modules or Array
- Battery Controller
- Batteries
- Plus an Inverter

These inverters convert direct current from the PV array and battery bank to alternating current

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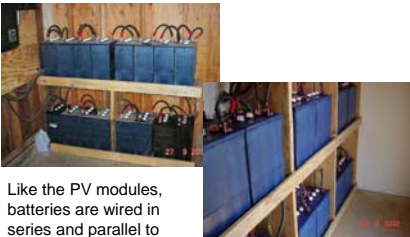
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## PV CELLS & COMPONENTS

### Batteries



Like the PV modules, batteries are wired in series and parallel to provide the voltage and amperage necessary for the operation of the electrical system

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## PV CELLS & COMPONENTS

### Battery Charge Controllers



Battery charge controllers are found in off-grid systems and grid-tied systems that have a battery back-up.

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## PV CELLS & COMPONENTS

### Mounting Systems

PV modules can be mounted directly on the roof, in many cases specialized roof racks lift the array from the roof deck allowing air to circulate under the modules.

Many PV systems are designed to withstand 80 mile per hour winds.

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## PV CELLS & COMPONENTS

### Mounting Systems

PV systems can also be mounted on the ground using customized racks, or they can be mounted on poles.



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## PV CELLS & COMPONENTS

### Other Solar Technologies

Two solar hot water panels are on the left of this roof and 44 modules of this 7 kw PV array on the right of this 3,000 sq. ft. home. The system is backed-up with a generator.

Solar thermal panels (solar water heating collectors) are used to heat water for the swimming pool or for domestic hot water

The long rectangular panel at the bottom of this array is a solar water heating panel.

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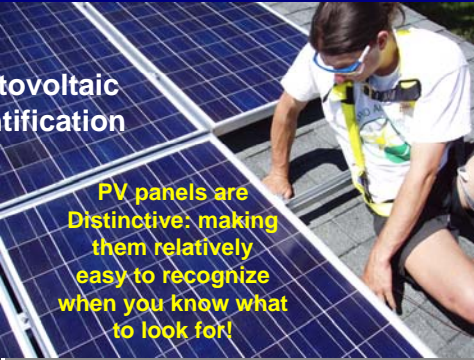
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**PV CELLS & COMPONENTS**

**Photovoltaic Identification**

PV panels are Distinctive: making them relatively easy to recognize when you know what to look for!

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**AGENDA**

- INTRODUCTION
- CELLS AND COMPONENTS
- PV PERFORMANCE
- PV APPLICATIONS
- CODES AND STANDARDS
- EMERGENCY RESPONSE

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**PV APPLICATIONS**

In December of 1998 Astronauts Jerry L. Ross (left) and James H. Newman work together on the final of three space walks of the STS-88 mission. (Photo Credit: NASA)

Even if you don't use PV directly you are doing so indirectly.

Communication systems and satellites with integrated PV systems provide power that improves the efficiency of our everyday lives even though you may not be aware of it!

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## PV APPLICATIONS

### Direct Current (DC) Systems



Components in a direct current system include:

- Photovoltaic module or array
- Battery charge controller
- Batteries and
- Direct current appliances

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## PV APPLICATIONS

### Grid-Tied System



This PV system includes:  
Solar Array & Inverter

This system allows the building owner to generate and use PV power during the day and deliver excess power directly to the utility grid

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## PV APPLICATIONS

### Grid-Tied System



Line-in from the array →

In this system the utility grid provides the back-up power and eliminates the need for batteries in the system

To insure that the inverter is disconnected once the main electrical panel is locked out, fire personnel can also use the manual disconnect next to the inverter as an extra precaution

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## PV APPLICATIONS

### Grid-Tied System



Loss of power from the grid will disconnect electricity in the building including the ability to use the electricity generated by the PV system

In this application where the inverter and main electrical panel is a distance from the meter another disconnect has been installed behind the meter on the utility pole

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## PV APPLICATIONS

### Commercial Grid-Tied System



You may not be able to see a PV system on a flat roofed building from street level. The large inverters at the USPS processing and distribution center in Marina Del Rey, would be your first clue of the existence of a 127 kw monocrystalline PV system on the roof.



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## PV APPLICATIONS

### BUILDING INTEGRATED DESIGN



The developing trend is to incorporate PV systems seamlessly into the building's exterior finish and landscape design

Laminated to the skylight glass are photovoltaic cells that produce electricity as well as serve as an element in the shading and day lighting design at the Thoreau Center for Sustainability, Presidio National Park, San Francisco, California.

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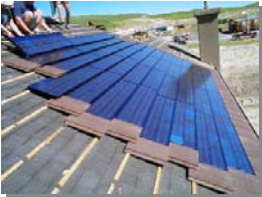
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## PV APPLICATIONS

### Photovoltaic Tiles and Shingles



Some manufacturers of PV roofing tiles have tested their products and meet the standard for Class A roofing

Manufacturers of PV shingles have achieved a Class A rating by using a fire resistant underlayment beneath the PV shingles

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## PV APPLICATIONS

### BUILDING INTEGRATED DESIGN



BID systems appear as PV roofing systems, windows, skylights or patio covers



PV canopies at CAL EXPO in Sacramento provide shade to parked cars

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## PV APPLICATIONS

### BUILDING INTEGRATED DESIGN



Blending this technology into traditional building and landscape design is one of the many challenges designers are involved in and presents new challenges for emergency responders in identifying PV technology when sizing-up an emergency

The solar cube stands 135 feet tall on top of the Discovery Science Center in Santa Ana, CA

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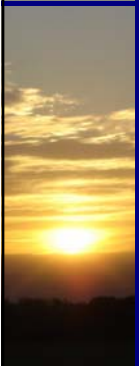
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	<h2 style="text-align: center;">CODES &amp; STANDARDS</h2>
	<p><b>California Electric Code (CEC) Article 690</b></p> <ul style="list-style-type: none"> <li>Circuit Requirements</li> <li>Wiring (conductor)</li> <li>System Disconnects</li> <li>Labeling</li> <li>Ground Fault Protection</li> <li>PV Modules &amp; Maximum System Voltage</li> <li>Batteries</li> </ul>

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	<h2 style="text-align: center;">CODES &amp; STANDARDS</h2>
	<p><b>Wiring Identification</b></p> <p>Direct current photovoltaic conductor (wiring) is run outside a building membrane with rated outdoor wiring</p> <p>The CEC specifies that conductors of different output systems will be contained in separate raceways, cable trays, cable, outlet box, junction box, or similar fittings</p>

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## CODES & STANDARDS

### System Disconnects

The Fire Code specifies that the disconnecting means is accessible to the fire department

In this system the inverter is flanked by two disconnects the right disconnects the array and the left disconnects the inverter from the main electrical panel

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## CODES & STANDARDS

### System Disconnect and Warning Labels

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## CODES & STANDARDS

### Ground Fault Protection

Locating the grounding connection point as close as practical to the photovoltaic source better protects the system from voltage surges due to lightning

Exposed non-current-carrying metal parts of module frames, equipment, and conductor enclosures shall be grounded regardless of voltage

Installer connecting ground wire to module frames.

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
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## CODES & STANDARDS

### PV Modules

In a PV module, the maximum system voltage is calculated and corrected for the lowest expected ambient temperature

This voltage is used to determine the voltage rating of cables, disconnects, overcurrent devices, and other equipment



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## CODES & STANDARDS

### PV Modules



Manufacturers provide rated information on the back of each panel.

- Operating current
- Operating voltage
- Maximum system voltage
- Short-circuit current

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## CODES & STANDARDS

### PV Batteries



Storage batteries in a photovoltaic system should be installed in accordance with the provisions of CEC Article 690 & CFC Chapter 6

Storage batteries for dwellings will have the cells connected to operate at less than 50 volts nominal

Lead-acid storage batteries for dwellings shall have no more than twenty-four 2-volt cells connected in series (48-volts nominal)

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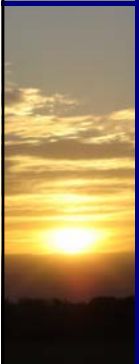
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	<h2 style="text-align: center;">EMERGENCY RESPONSE</h2>
	<p><b>Fire Fighter Hazards</b></p> <ul style="list-style-type: none"> <li>Inhalation Exposure Hazards</li> <li>Electrical Shock &amp; Burns</li> <li>Falls from Roof Operations</li> <li>Roof Collapse</li> <li>Batteries</li> </ul> <p><b>Emergency Response</b></p> <ul style="list-style-type: none"> <li>How do you work with PV</li> <li>What not to do around PV</li> </ul>

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	<h2 style="text-align: center;">EMERGENCY RESPONSE</h2>
	<p><b>Inhalation Hazards</b></p> <div style="display: flex; align-items: center;">  <div style="margin-left: 10px;"> <p>During a fire or explosion the PV frame can quickly degrade exposing hazardous chemicals to direct flame and become dissipated in the smoke plume</p> </div> </div>

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## EMERGENCY RESPONSE

### Electric Hazards

The physiological effects produced by electricity flowing through the body include:

**Perception** – (1 mA) tingling sensation

**Startle Reaction** – (5 mA) involuntary muscle reaction

**Muscle Tetanization** – (6 to 30 mA) painful shock

**Respiratory Arrest** – (.5 to 1.50 Amps) stop breathing

**Ventricular Fibrillation** – (1 to 4.3 Amps) heart stops

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## EMERGENCY RESPONSE

### Roof Hazards

In roof operations consider the weight of the PV array on a weakening roof structure and the fact that you may not be able to access the roof over the fire



To cut ventilation, select a spot at the highest point of the roof and as close to the fire as possible

Do not cut into PV modules!

Consider cross ventilation?

Roof vents, skylights, solar thermal panels, and PV array pose a trip hazard to fire fighters conducting roof operations

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## EMERGENCY RESPONSE


### Battery Hazards

As a rule, batteries do not burn; or rather, they burn with great difficulty

If batteries are exposed to fire, however, the fumes and gases generated are extremely corrosive

Spilled electrolyte can react and produce toxic fumes and release flammable and explosive gases when it comes into contact with other metals

Due to the potential of explosive gases, prevent all open flames and avoid creating sparks



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## EMERGENCY RESPONSE

### Personal Protective Equipment

Firefighters should follow the minimum standard in NFPA 1971, Protective Ensemble for Structural Firefighting and NFPA 1500, Chapter 7 Personal Protective Equipment

This would include:

- Turnout pants
- Turnout coat
- Boots
- Gloves
- Hood
- Helmet
- SCBA

*Note: Jewelry such as; watches, rings, and necklaces are all a good conductor of electricity and should not be worn around electrical components*

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## EMERGENCY RESPONSE

### Emergency Operations

**Size-Up** – the roof and look for warning labels on electrical disconnects

**Lock-Out & Tag-Out** - all electrical disconnects, isolating the PV system at the inverter

**Ventilation** - consider where to cut or whether to use cross ventilation

**Shelter-in-Place** – Does the size of the emergency and the involvement of the array constitute the need to protect populations downwind?

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## EMERGENCY RESPONSE

### Emergency Operations

The PV array will always generate electricity when the sun shines- there is no turning it off!

Walking or breaking PV modules could release all the energy inherent in the system simultaneously

Cut or damaged wires from a nighttime operation could become energized in the day-time

Spotlights during an evening operation is not bright enough for the PV system to generate electricity

Lightening is bright enough to create electrical surge!

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## EMERGENCY RESPONSE

### Emergency Operations

Long Beach Convention Center




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## EMERGENCY RESPONSE

### Emergency Operations

You cannot block all the sunlight on the array with foam or a salvage cover



Foam will not block out all the sunlight and will slide off the array

Salvage cover will significantly reduce sunlight to the array but electricity can still be generated through the material of the salvage cover

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## SUMMARY

Your fundamental understanding of photovoltaic systems will improve your confidence in working with and around solar technology safely.

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